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Pre-Clovis Mastodon Hunting 13,800 Years Ago at the Manis Site, Washington

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alternative to the ultimate dependence on orbital tuning. In addition to providing an absolute time scale for the ice and gas records from Antarctica, we can also use our absolutely dated Greenland reconstruction as a tuning target for other high-resolution paleo-records, such as records of ice-rafted debris (IRD) from a North Atlantic sediment core (*4*) and a record of sea surface temperature (SST) from a core off the Iberian Margin (*27*) (Fig. 4). Each of these records has been tuned to our reconstruction on its absolute time scale (*6*).

Our synthetic records confirm that millennial time scale variability and abrupt climate oscillations occurred in Greenland throughout the past 800,000 years, and more specifically they suggest that the underlying physical mechanisms represented by the conceptual thermal bipolar seesaw were relatively invariant throughout this period. In line with observations for the last glacial period (*28*), our reconstructions suggest that higher-amplitude variability and more frequent D-O–like warming events occurred when climate was in an intermediate state or during the transitions between states (Fig. 4). Extending the observations of (*22*), we find that glacial terminations of the Middle to Late Pleistocene in general were characterized by oscillations of the bipolar seesaw.

This apparently ubiquitous association of millennial-scale climate variability with glacial terminations raises an important question: Is this mode of variability a necessary component of deglacial climate change, or merely a complicating factor? Previous studies (*28*, *29*) have suggested that D-O–type variability might represent an inherent resonance of the climate system, attaining a high amplitude only within certain windows of opportunity (i.e., intermediate climate states). Given that global climate must pass through such a window during deglaciation, one could argue that terminal oscillations of the bipolar seesaw are merely a symptom of deglacial climate change (*29*). However, the precise correspondence observed between bipolar seesaw oscillations and changes in atmospheric CO_2 during glacial terminations (Fig. 4) suggests that the bipolar seesaw may play more than just a passive role in the mechanism of deglaciation (i.e., through the positive feedbacks associated with increasing CO_2) (*14*, *19*, *22*). With the supercritical size of continental ice sheets as a possible precondition (*30*), and in combination with the right insolation forcing (*31*) and ice albedo feedbacks, the CO_2 rise associated with an oscillation of the bipolar seesaw could provide the necessary additional forcing to promote deglaciation. In this sense, the overall mechanism of glacial termination during the Middle to Late Pleistocene might be viewed as the timely and necessary interaction between millennial and orbital time scale variations.

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Supporting Online Material
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Figs. S1 to S14
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Pre-Clovis Mastodon Hunting 13,800 Years Ago at the Manis Site, Washington

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The tip of a projectile point made of mastodon bone is embedded in a rib of a single disarticulated mastodon at the Manis site in the state of Washington. Radiocarbon dating and DNA analysis show that the rib is associated with the other remains and dates to 13,800 years ago. Thus, osseous projectile points, common to the Beringian Upper Paleolithic and Clovis, were made and used during pre-Clovis times in North America. The Manis site, combined with evidence of mammoth hunting at sites in Wisconsin, provides evidence that people were hunting proboscideans at least two millennia before Clovis.

Recent studies have strengthened the case that the makers of Clovis projectile points were not the first people to occupy the Americas (*1*–*5*). If hunting by humans was responsible for the megafauna extinction at the end of the Pleistocene (*6*), hunting pressures must have begun millennia before Clovis (*7*). Here we reexamine the evidence from the Manis site in the state of Washington (*8*), an early mastodon kill that dates to 800 years before Clovis.

Between 1977 and 1979, a single male mastodon (*Mammut americanum*) was excavated from sediments at the base of a kettle pond at the Manis site (figs. S1 to S3) (*8*–*10*). Some bones were spirally fractured, multiple flakes were removed from one long bone fragment, and other bones showed cut marks (*8*, *11*, *12*). The only documented artifact associated with the mastodon was a foreign osseous fragment, interpreted as the tip of a bone or antler projectile point,

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embedded in a rib fragment that was recovered ex situ from sediments excavated when a backhoe uncovered the bone bed (Fig. 1 and fig. S4) (*8*). Organic matter associated with the mastodon yielded calibrated radiocarbon ages of ~14 thousand years ago (ka) (*8, 10*) (table S1). Over the past 35 years, the age and evidence for human involvement with the Manis mastodon have been challenged (*13*).

We obtained 13 accelerator mass spectrometry (AMS) ^{14}C dates from purified bone collagen (*4*) extracted from the mastodon rib containing the embedded osseous object and from both tusks (table S2). All dates were statistically identical at 1 SD and establish an age of 11,960 ± 17 ^{14}C years before the present (yr B.P.) for the Manis mastodon (Table 1; average of four XAD fractions; 13,860 to 13,765 calendar yr B.P.) (*14*). These dates show that the ex situ mastodon rib and in situ skeleton are contemporaneous.

High-resolution x-ray computed tomography (CT) scanning (*15*) revealed that the osseous object embedded in the rib is dense bone shaped to a point (Fig. 1 and movies S1 and S2). The point penetrated 2.15 cm into the rib; the tip broke after entering the rib and separated from the main shaft. The combined length of the point fragment (tip length plus the length of the embedded and external shaft piece) is 3.5 cm.

The rib with the embedded projectile point is a right 12th, 13th, or 14th rib in a series of 19, but most likely the 14th rib (Fig. 2). The projectile point entered the dorsal surface of the proximal end of the rib immediately distal to the lateral margins of the two articular facets at approximately a 45° angle relative to the axis of the head of the rib. The point would have penetrated the hair and skin and about 25 to 30 cm of superficial epaxial muscles (Fig. 2 and fig. S5). Thus it was at least 27 to 32 cm long, comparable with the known length of later, Clovis-age thrown and thrust bone points (*16*). There is no evidence of bone growth around the point, indicating that the mastodon died soon after it was attacked.

DNA and protein sequencing were undertaken on the rib and bone point (supporting online material text 4 and 5). Attempts to amplify a 140–base pair (bp) fragment of the 16*S* mitochondrial DNA (mtDNA) from the rib using universal vertebrate primers (*17*) produced only modern (human) contamination. However, redesigning primers for a 69-bp fragment (including primers, table S8) of D-loop mtDNA produced sequences from both the rib and bone point that were identical to mastodon and distinct from other proboscideans (mammoth or elephant) by nine substitutions.

We also obtained high-resolution tandem mass spectrometry (MS/MS)–based protein sequences from the projectile point and rib, and used another mastodon sample as a second reference (tables S3 to S6). The MS/MS spectra from the bone point matched the reconstructed mastodon collagen sequences, with the highest scores being within a reference set of collagen sequences (table S7 and supporting table of bone point marker peptides). These results and controls show that the point was fashioned from mastodon bone.

The Manis site provides further evidence of a human presence in the New World 800 years before Clovis [13 ka (*4*)] and shows that people were hunting with mastodon bone weapons made from earlier kills. Evidence for pre-Clovis hunting also comes from the 14.2-ka Schaefer site and 14.8-ka Hebior site, Wisconsin (*18*, *19*), where stone artifacts, but no projectile points, were found with the remains of mammoth (*Mammuthus primigenius*). Additional evidence of megafauna hunting comes from sites where artifacts are absent, but taphonomic evidence suggests human butchering, such as at the 13.8-ka Ayer Pond site (45SJ454), Orcas Island, Washington (*20*). Studies of the dung fungal spore *Sporormiella* from lakes in Indiana and New York imply that megafauna populations collapsed there between 14.8 and 13.7 ka (*7*). Thus, the impact of human hunters on the North American megafauna was more prolonged than previously hypothesized and was not a "Clovis blitzkrieg" (*21*). The absence of stone projectile points at Manis, Hebior, Schaefer, and Orcas Island and the presence of an osseous projectile point at Manis suggest that osseous projectile points may have been the predominant hunting weapon during the pre-Clovis period. Bone and ivory points and other tools are common in the Upper Paleolithic of Siberia and in late Pleistocene sites in Beringia (*22*–*24*). They are durable and lethal hunting weapons that continued to be used during and after Clovis (*16*, *23*, *25*). The invention and spread of a new hunting weapon at 13 ka—the Clovis lithic point—may have accelerated the demise of or doomed the last megafaunal species.

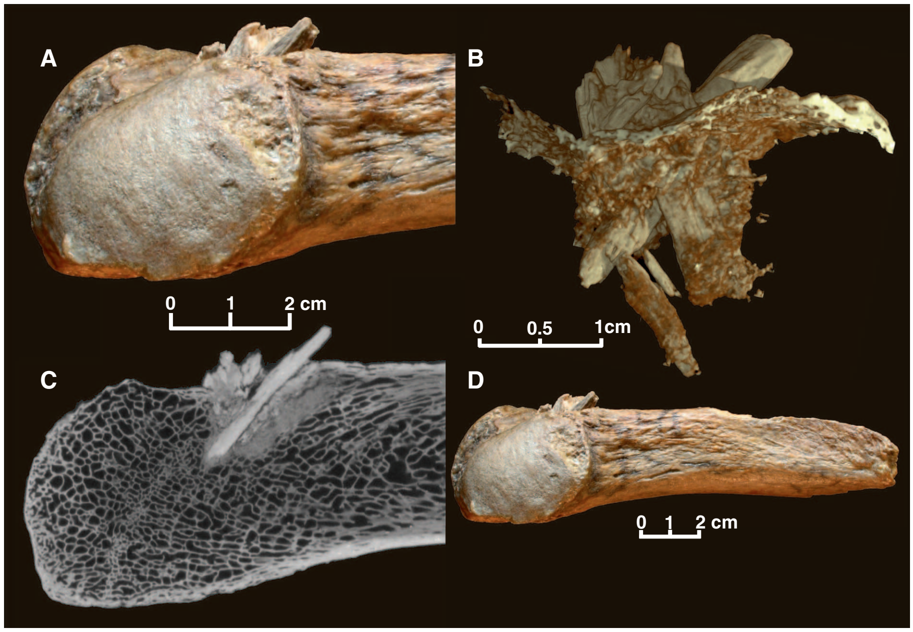

Fig. 1. Mastodon rib with the embedded bone projectile point. (**A**) Closeup view. (**B**) Reconstruction showing the bone point with the broken tip. The thin layer represents the exterior of the rib. (**C**) CT x-ray showing the long shaft of the point from the exterior to the interior of the rib. (**D**) The entire rib fragment with the embedded bone projectile point.

Table 1. AMS ^{14}C ages used to date the Manis Mastodon.

Specimen dated	Date (^{14}C yr B.P. ± 1 SD)	Lab number	Material dated
Mastodon tusk ivory sample no. 1	11,975 ± 35	UCIAMS-11350	XAD-gelatin (KOH collagen)
Mastodon tusk ivory sample no. 1	11,975 ± 35	UCIAMS-12046	XAD-gelatin (KOH collagen)
Mastodon tusk ivory sample no. 2	11,890 ± 35	UCIAMS-11677	XAD-gelatin (KOH collagen)
Mastodon rib with embedded bone projectile point	11,990 ± 30	UCIAMS-29113	XAD-gelatin (KOH collagen)
Average of four radiocarbon measurements	11,960 ± 17 ^{14}C yr B.P. (13,860 to 13,763 calendar yr B.P.)	—	n = 4 XAD-gelatin (KOH collagen)

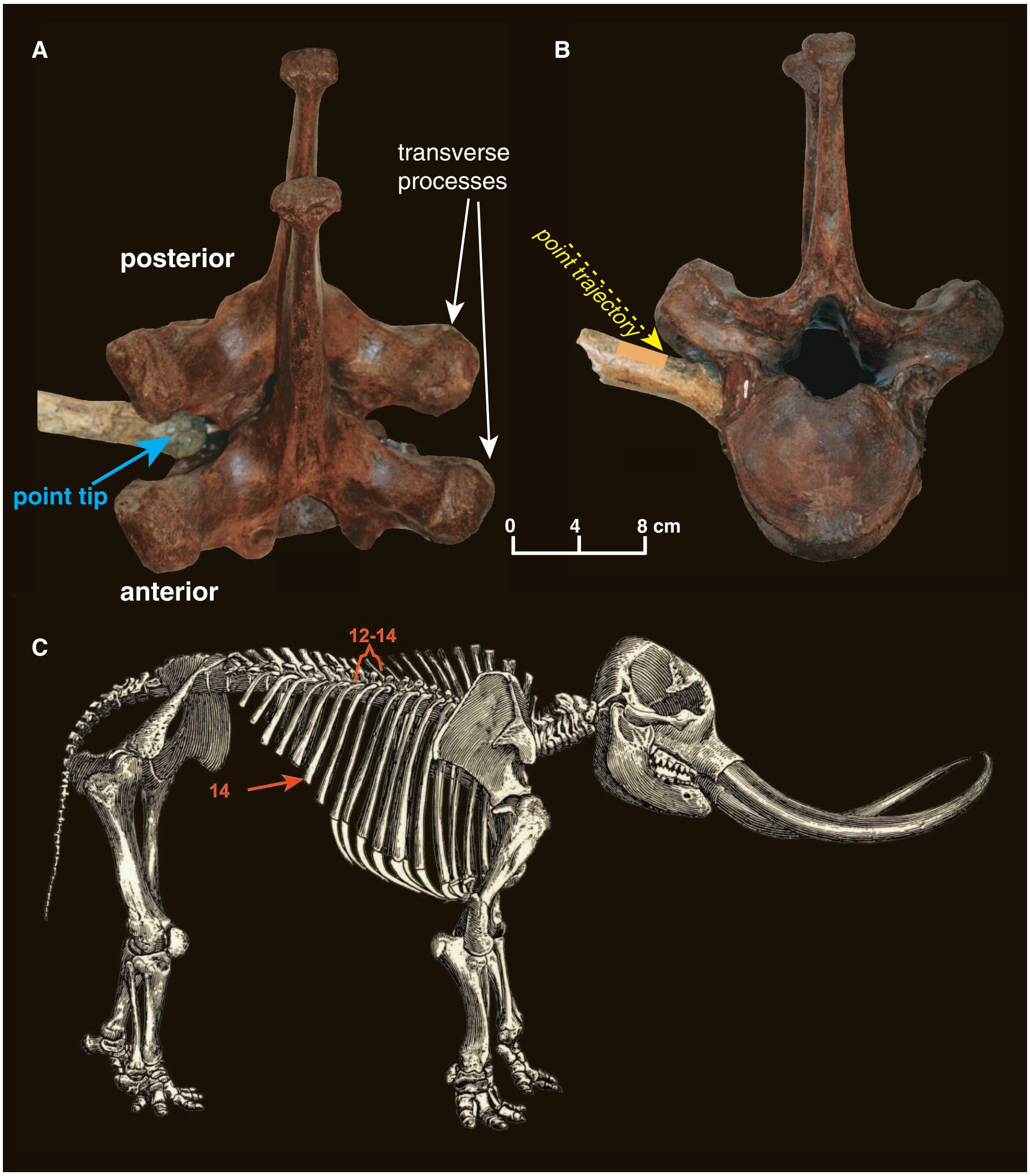

Fig. 2. Anatomical position of the Manis rib. (**A**) Two vertebrae with the Manis rib inserted into its correct anatomical position. The blue arrow points to the embedded point fragment. (**B**) Side view of mastodon vertebrae with the Manis rib inserted into its correct anatomical position, with the trajectory of the point indicated. (**C**) Mastodon skeleton showing the location of ribs 12 to 14.

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Supporting Online Material

www.sciencemag.org/cgi/content/full/334/6054/351/DC1
SOM Text
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References
Table of bone point marker peptides

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